International Test and Evaluation Association
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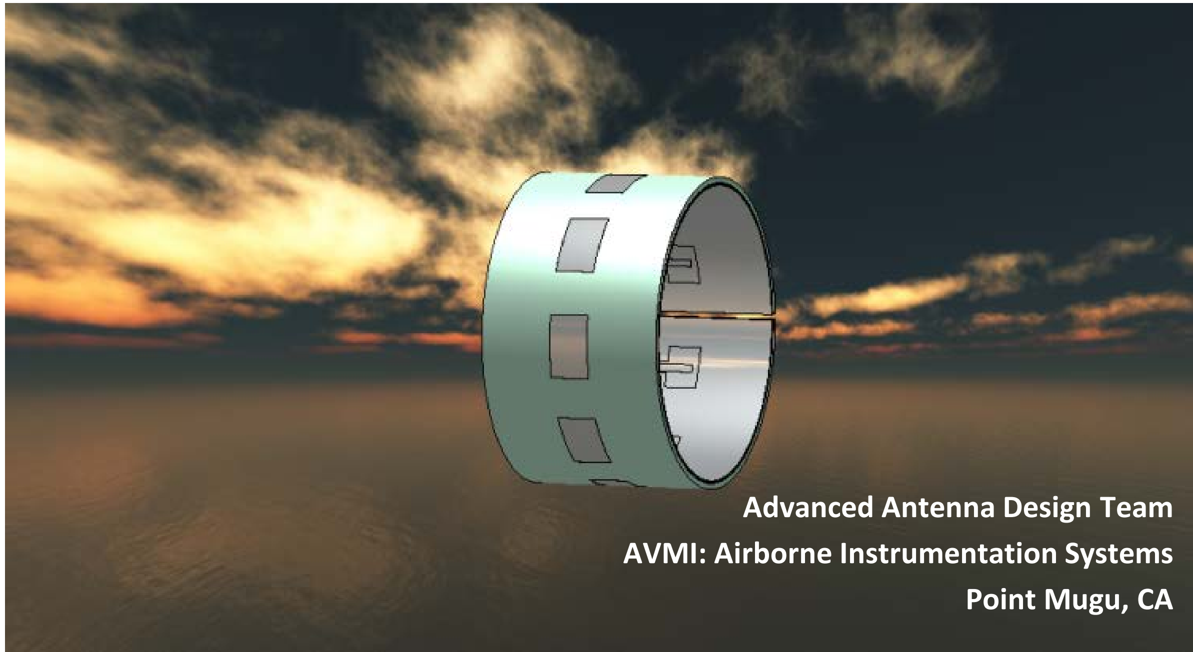
412TW-PA-19266

Spectrum Access R&D (SARD) Program: Broadband Conformal C-Band Antenna Project

Ensuring Warfighting Superiority



Advanced Antenna Design Team
AVMI: Airborne Instrumentation Systems
Point Mugu, CA

Background: AWS-3 Auction

- Advanced Wireless Services-3
  - Leverage and augment available spectrum in C-Band
    - 4400 MHz – 4940 MHz
    - 5091 MHz – 5015 MHz
  - Relocate, compress, and augment telemetric capabilities
    - *Investigate operational trade-offs from S-Band to C-Band*
    - Invest and upgrade in infrastructure, hardware, and software
  - Mature fielded systems and integrate with new range requirements

Background: Transitioning TM Bands

- Wavelength vs. Frequency
  - S-band Wavelength: 5.26” @ f_{center} = 2245 MHz
  - C-Band Wavelength: 2.47” @ f_{center} = 4775 MHz

Decreased wavelength forces higher element count around missile roll axis

- Transmit Conformal Wraparound Antennas
  - *“…C-band antenna contains twice as many elements as the S-band antenna, the interference patterns tend to get more complicated and can be harder to control. As a result, it might be more difficult for a C-band wrap-around antenna to meet a “90% of the gain values must be greater than -7 dBi” specification.”* [1]
- Receive Dish Antennas
  - Retrofitting and upgrading existing telemetry acquisition & tracking dishes for C-Band operation
    - For a fixed dish diameter, gain increases as wavelength decreases
    - Proportion of dish diameter to wavelength produces narrower beam-width

$$G_0 = \left(\frac{\pi D}{\lambda}\right)^2 \eta_i$$

- Link Analysis
  - Conformal antenna EIRP: decreased
  - Receive dish G/T: increased
  - Spreading loss: increased
  - Component loss: increased
  - Additional loss: increased
  - Beamwidth: decreased

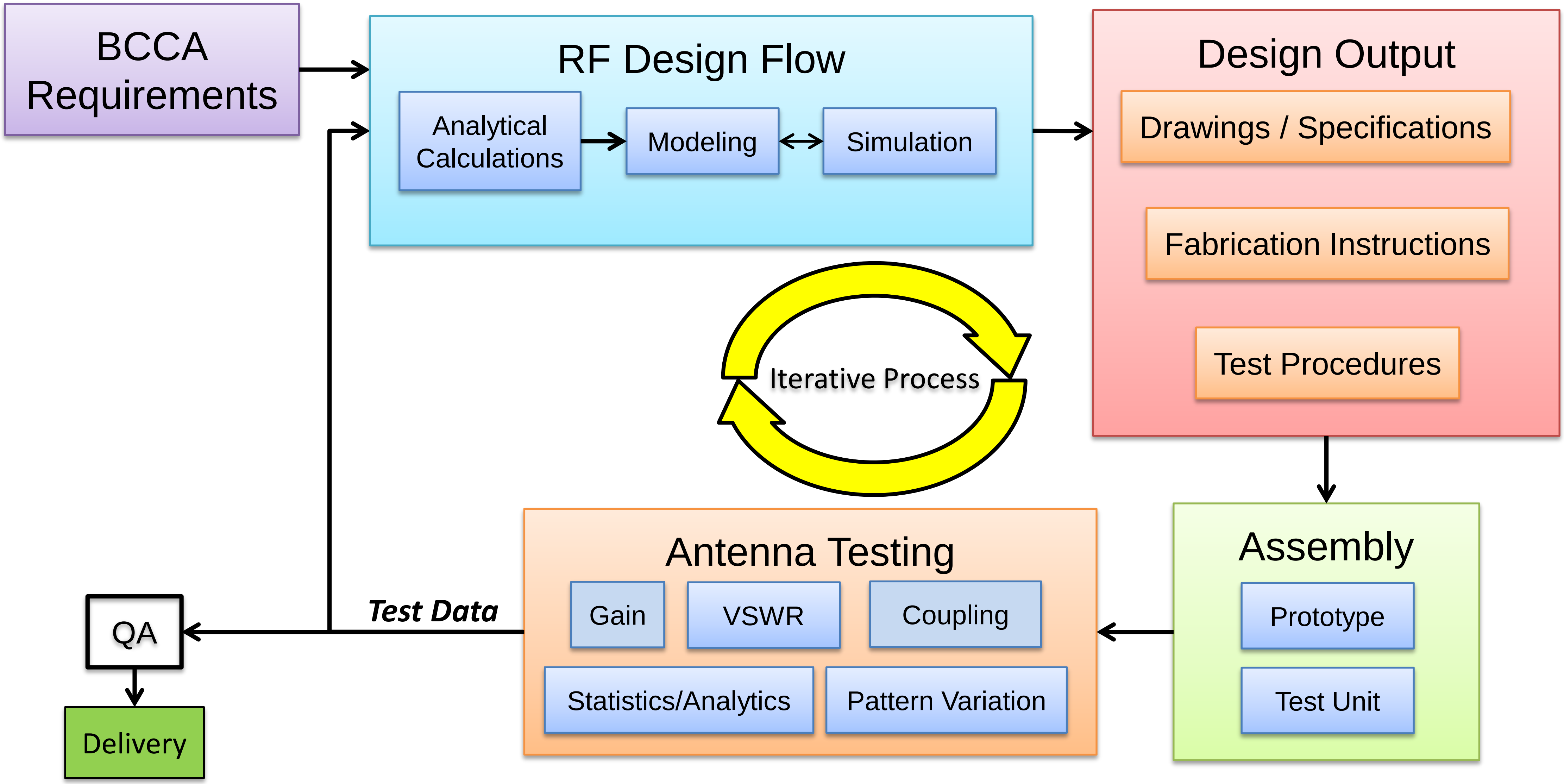
$$\left[\frac{C}{N_0}\right]_{\text{dB}} = \underbrace{\left[P_T G_T(\theta,\phi)\right]_{\text{dB}}}_{\text{EIRP}} + \underbrace{\left[\left(\frac{\lambda}{2\pi R}\right)^2\right]_{\text{dB}}}_{\text{spreading loss}} + \left[\frac{G_R(\theta',\phi')}{T_{\text{eq}}}\right]_{\text{dB}} - [k]_{\text{dB}} - [L]_{\text{dB}}$$

Net Loss: Increased

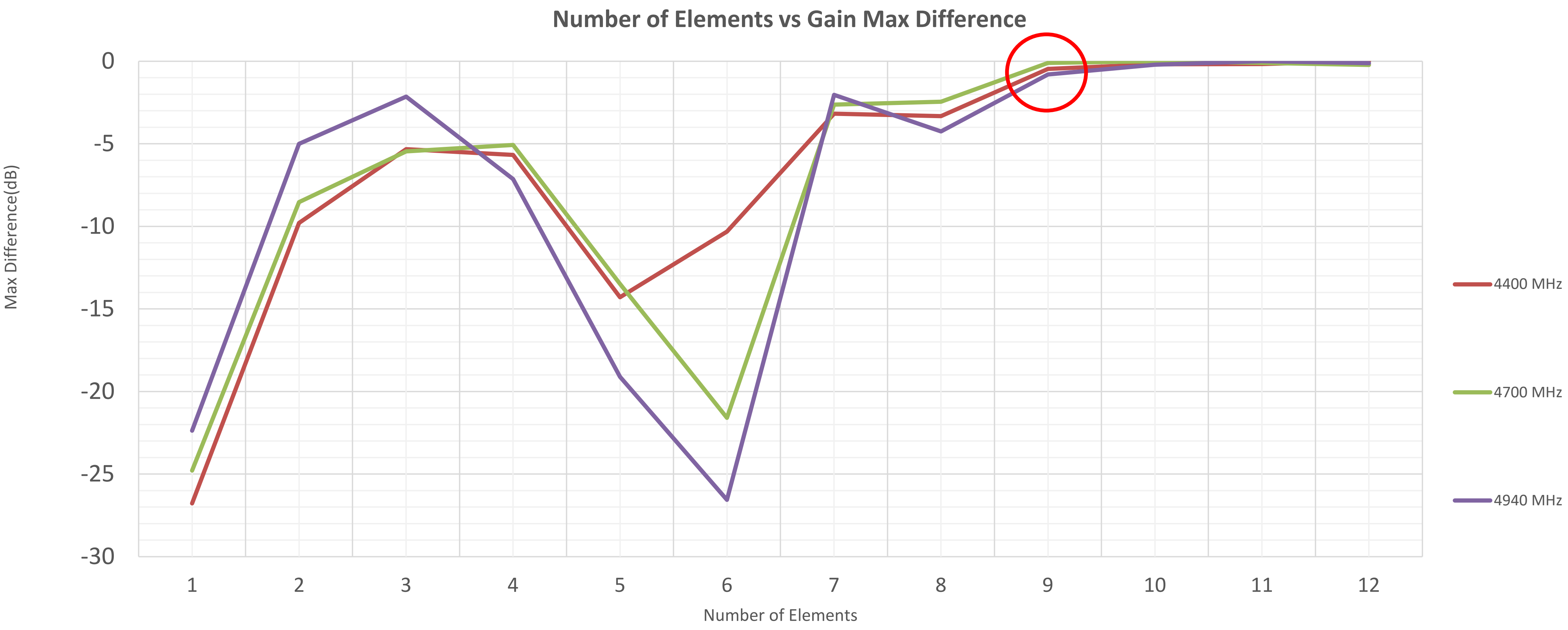
- Bottom Line Up Front
  - *“The main point is a c-band missile telemetry system must operate with less link margin than an s-band missile telemetry system. How much of a problem this is depends on the application.”* [2]

[1,2] *AFFTC-PA-12423: The Challenges of C-Band Missile Telemetry, M. Rice, 2013*

T&E: Antenna Design Lifecycle

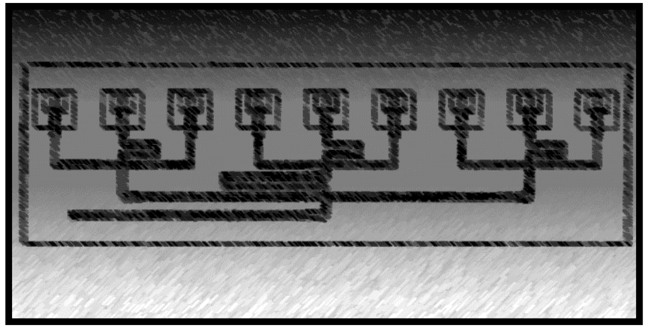


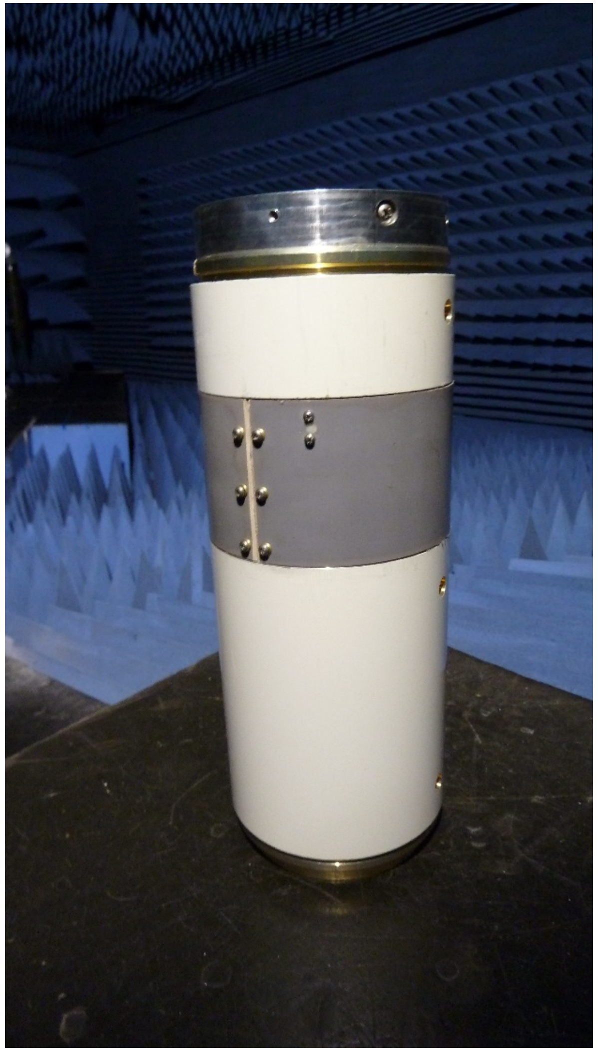
Analysis of Alternatives



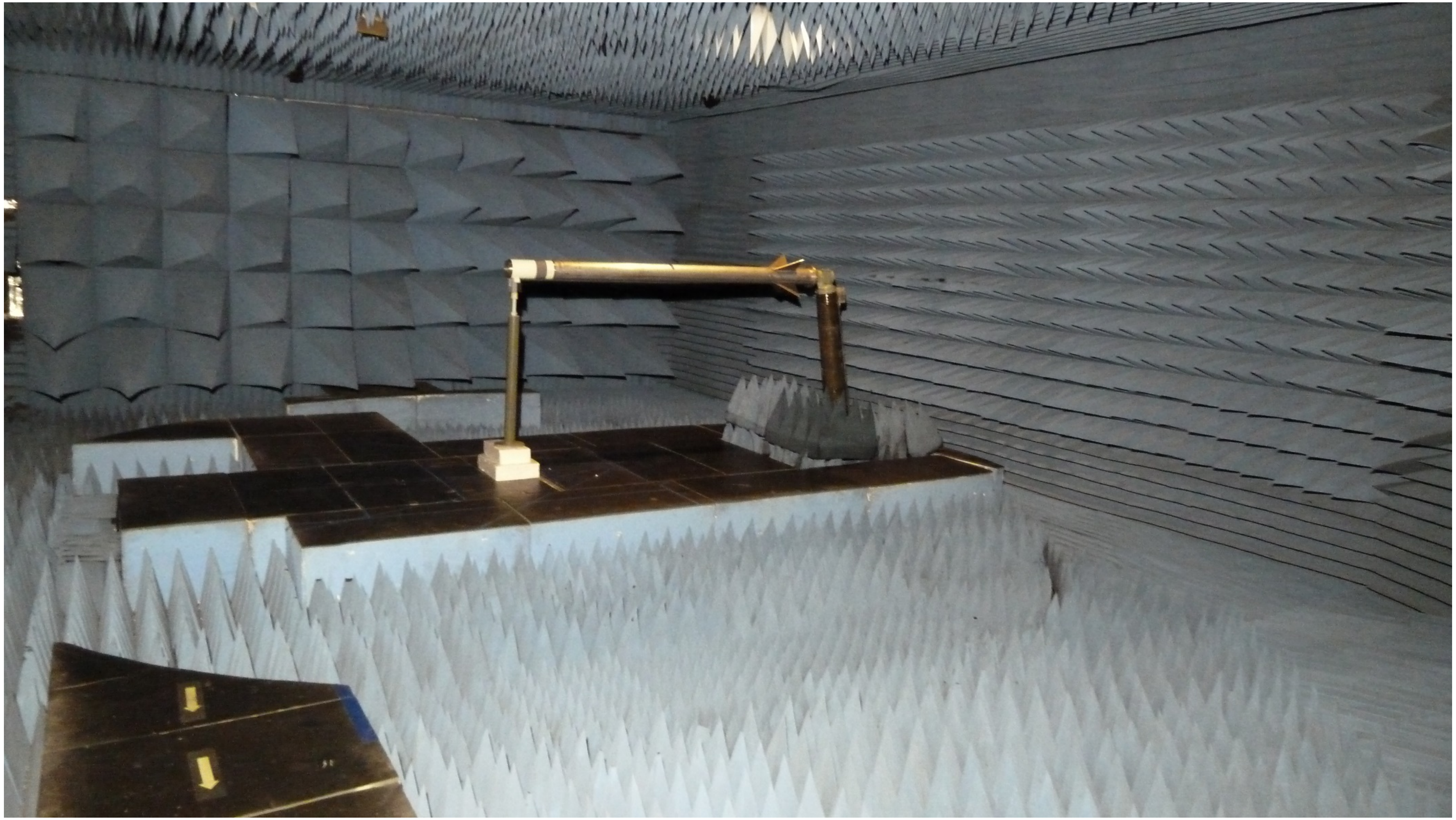
9-Element Conformal Antenna

- Design Approach
  - Antenna Configuration
    - C-Band ready
    - Broadband complex impedance match
    - Form-Fit footprint
    - Highest efficiency
    - Multilayered
    - Reduced gain variation
  - Power distribution objectives
    - Reduce inter-element coupling
    - Reduce feed-to-element coupling
    - Reduce insertion loss
    - Retain phase stability
    - Maintain amplitude stability



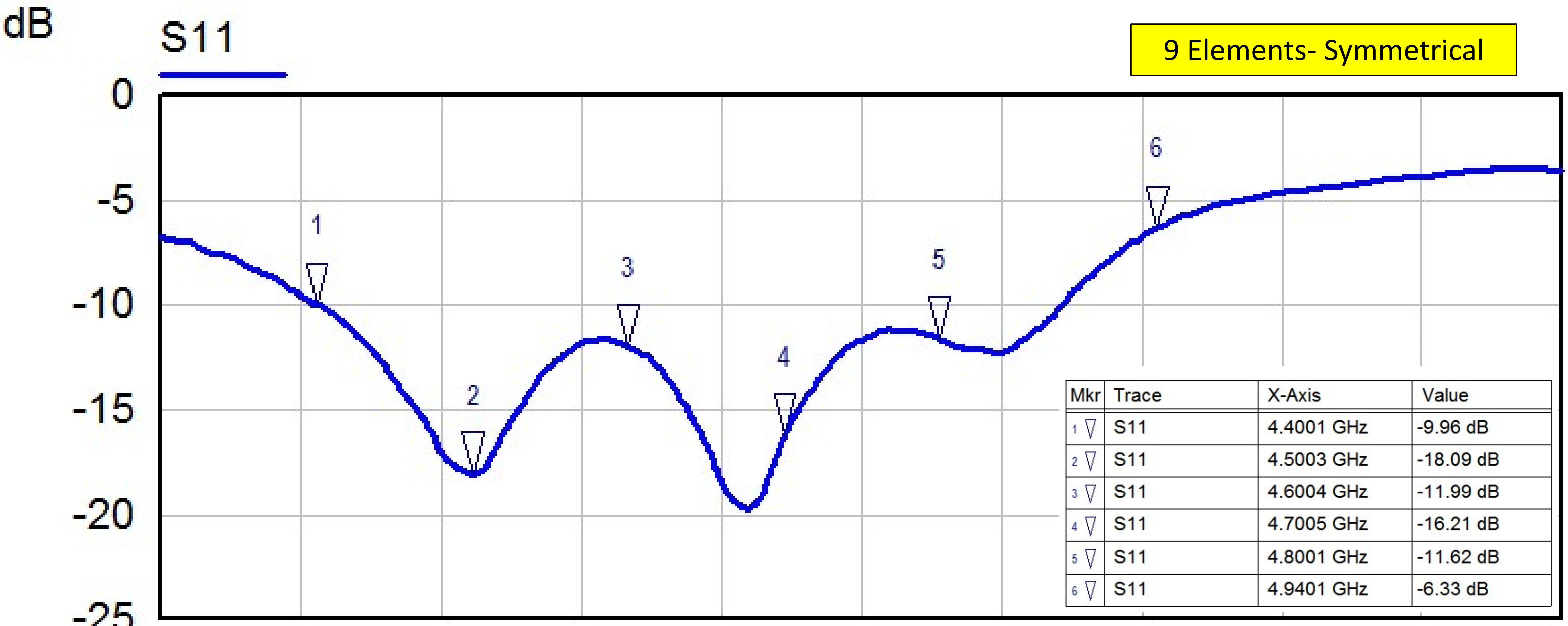


Chamber Mockup



Measured Data: Return Loss

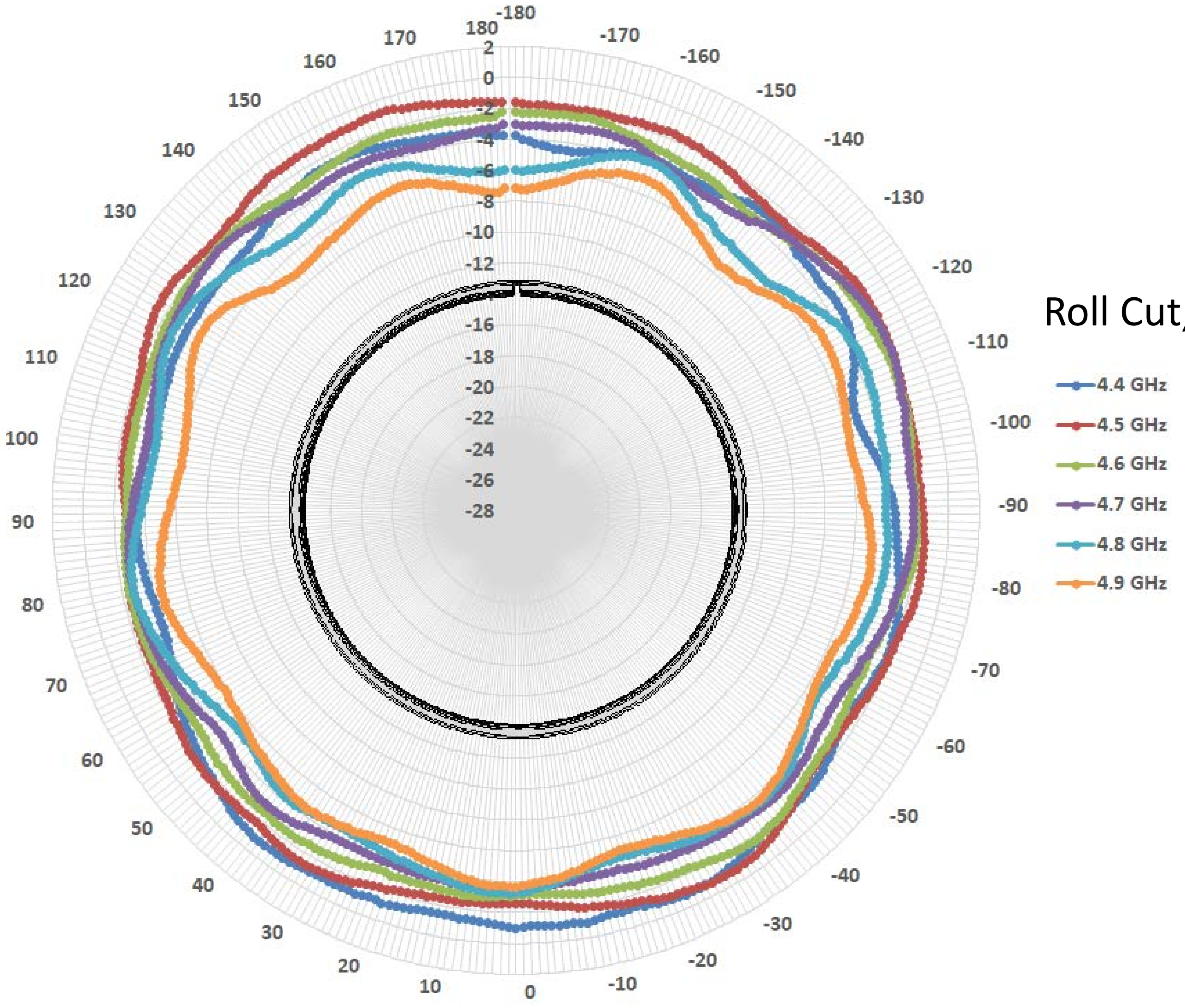
9 Elements- Symmetrical



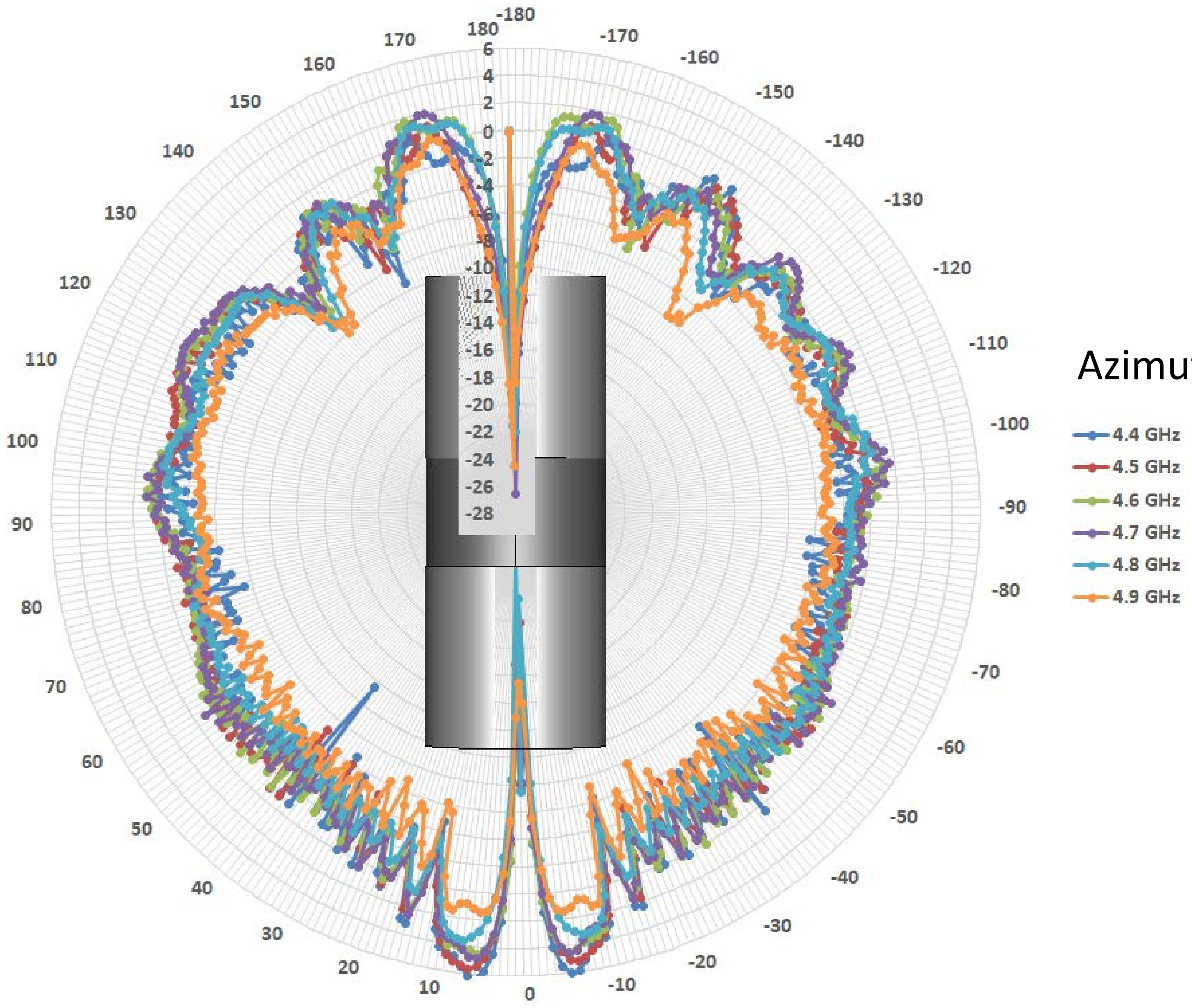
Mkr	Trace	X-Axis	Value
1 ▽	S11	4.4001 GHz	-9.96 dB
2 ▽	S11	4.5003 GHz	-18.09 dB
3 ▽	S11	4.6004 GHz	-11.99 dB
4 ▽	S11	4.7005 GHz	-16.21 dB
5 ▽	S11	4.8001 GHz	-11.62 dB
6 ▽	S11	4.9401 GHz	-6.33 dB

Approximately 440 MHz <2:1 VSWR BW

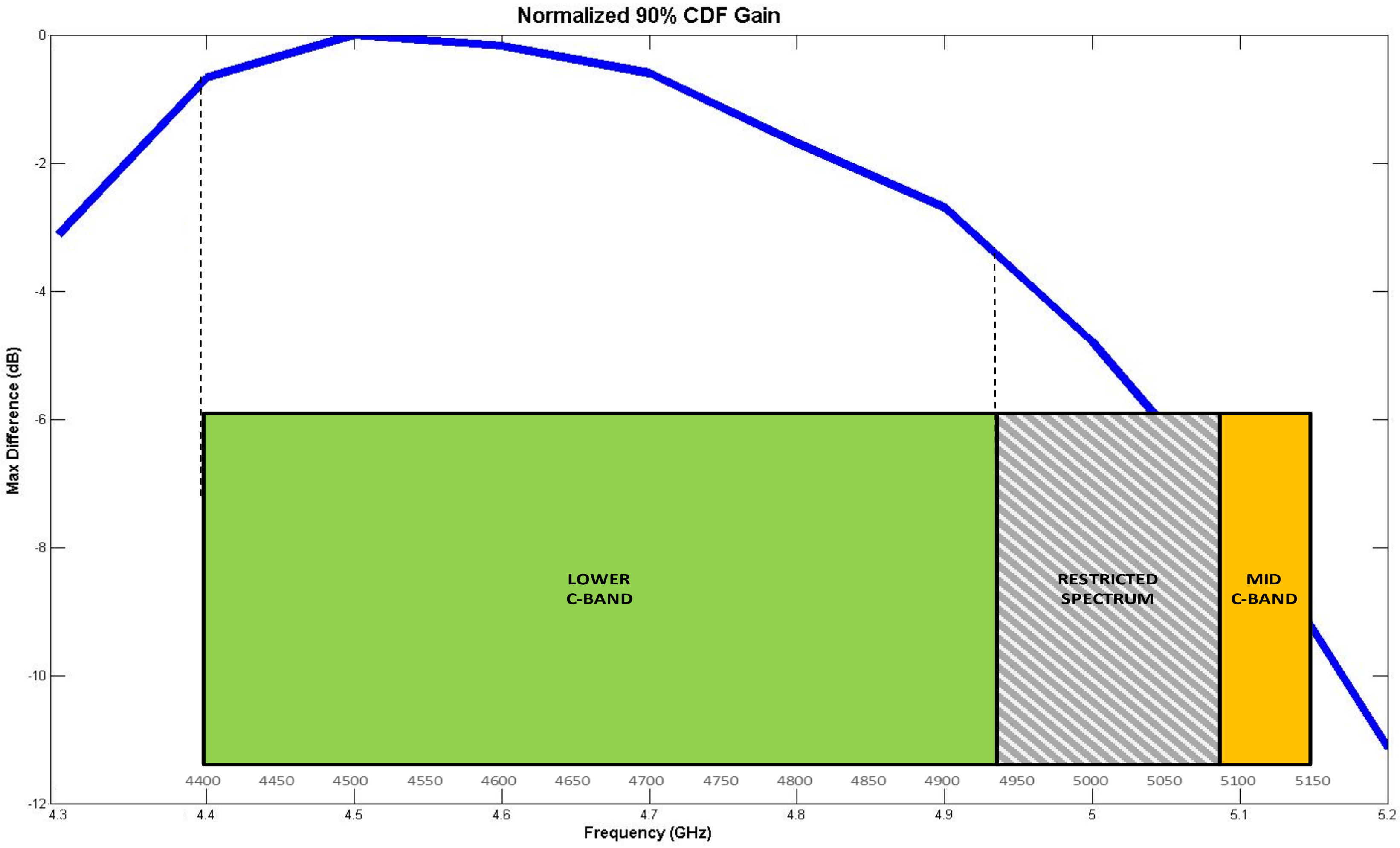
Measured Data: Realized Gain



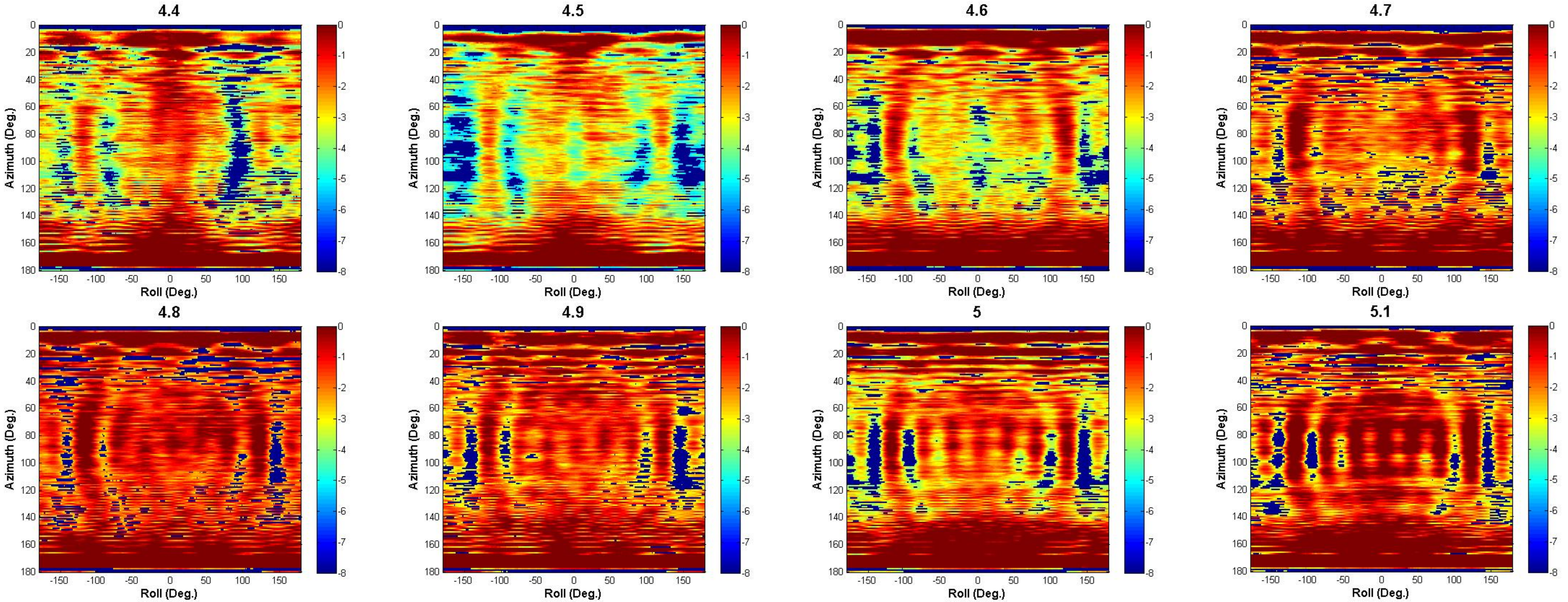
Measured Data: Realized Gain



Measured: 90% of Gain Data



Measured: Normalized Gain Plots



Link Analysis: TM Band Comparison

Location	Link Range S-Band	Link Range C-Band	S vs. C Delta	Test Range Size
China Lake	54.4	52.6	1.8	35
Eglin	97.8	72.1	25.7	187
Mugu	146.5	148.4	1.9	116
SNI	58.3	148.4	90.1	116

*C-Band gain value obtained from DP01

Summary

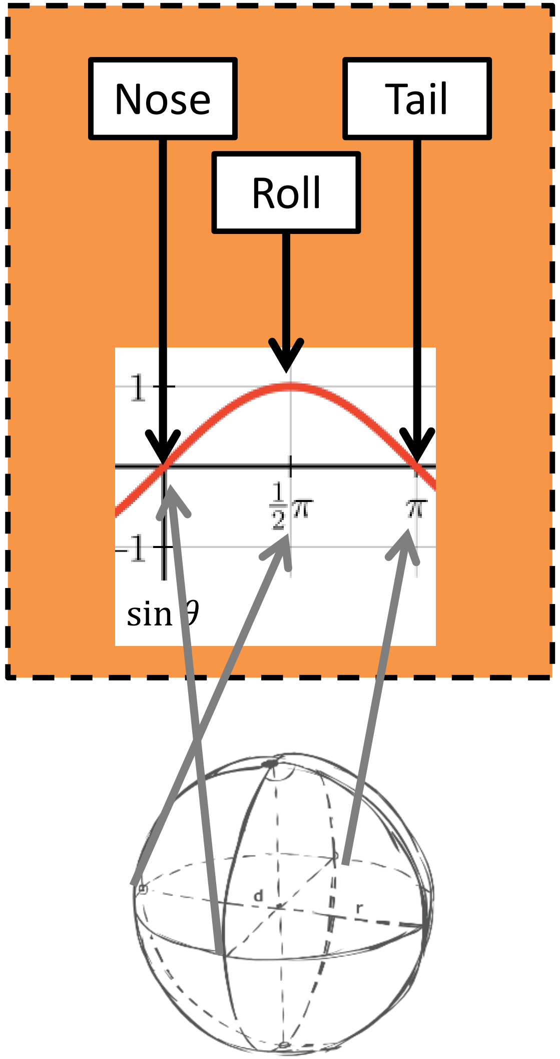
- Designed and Developed Broadband C-Band Conformal Antenna
  - Characterized RF performance
  - Maximized ERP Performance
  - Matured aerodynamic and mechanical footprint
  - Analyzed TM link performance with Test Range Data
  - Presented S-Band vs. C-Band Tradeoffs

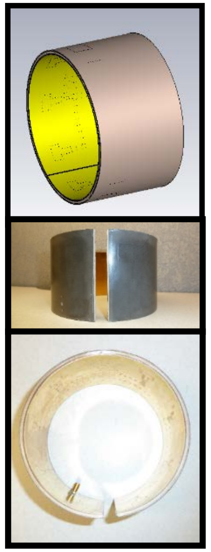
QUESTIONS?

BACKUPS

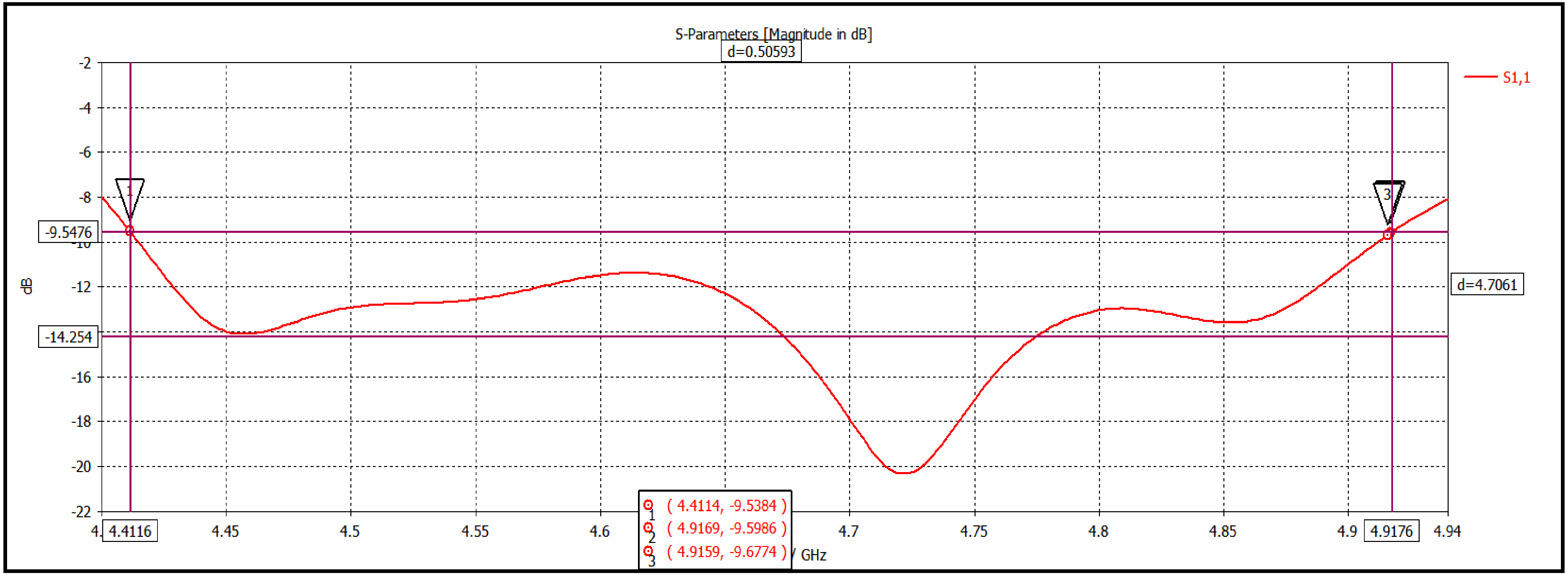
Intensity Plots: Spherical Data

- X Axis = Roll (ϕ)
- Y Axis = Azimuth (θ)
- Weight Distribution: sin(θ)
  - Poles become negligible
  - Roll weight highest, θ = 90°
- Gain
  - Highest Gain: Red/Yellow
  - Lowest Gain: Purple/Blue



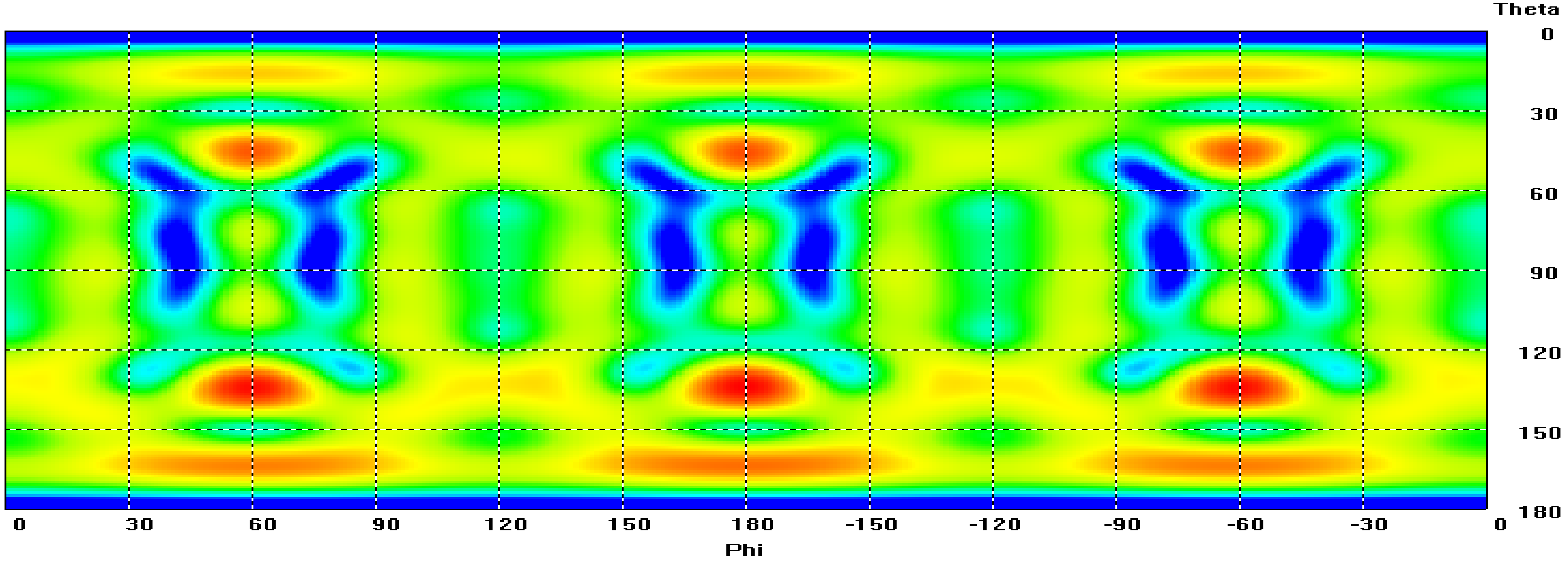


Simulation Data: Return Loss

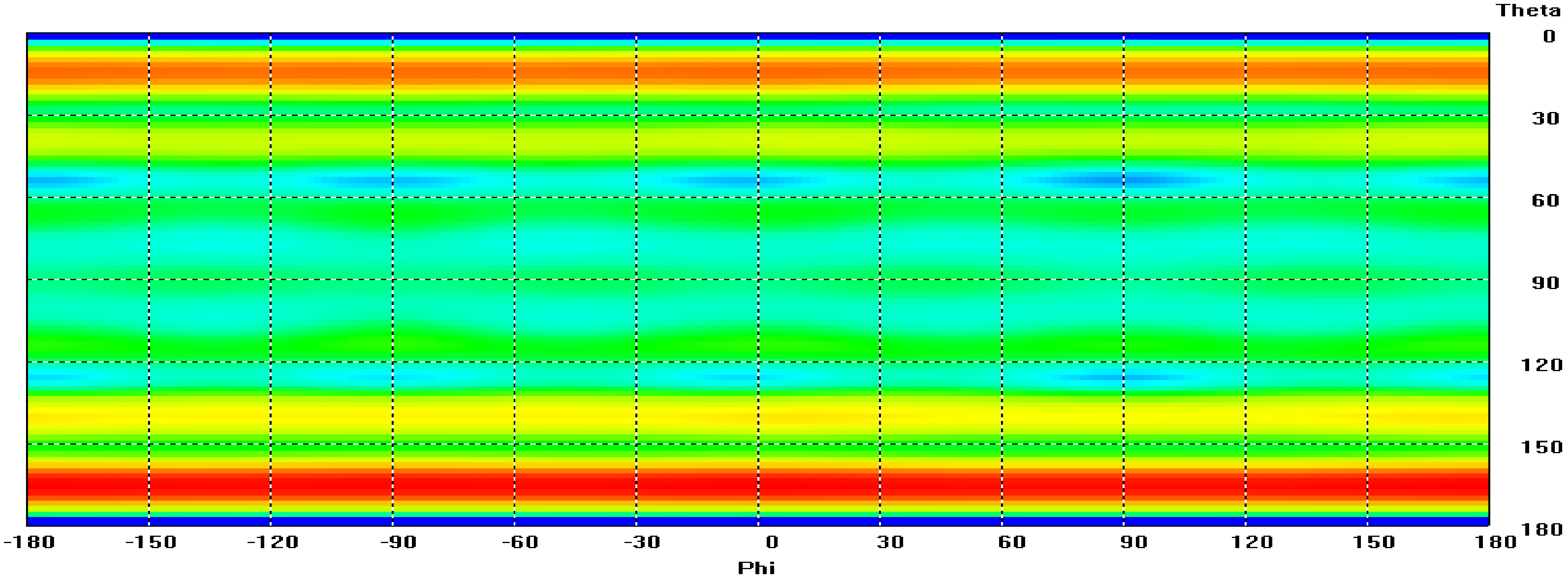


Approximately 500 MHz <2:1 VSWR BW

Simulation: 3 Element Configuration



Simulation: 11 Element Configuration



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14. ABSTRACT
With an available RF bandwidth of 599 MHz for telemetry and aeronautics, transition into lower and middle C-Band spectrum operations across national test ranges demands development and maturation of critical transmit and receive components for weapons, targets, and aircraft applications.
Through collaboration of the Test Resource Management Center and Department of the Navy, The Broadband Conformal C-Band Antenna (BCCA) project addresses design, characterization, and maturation of aerodynamic cylindrical conformal antennas in maximizing performance for optimal telemetry range wireless links.
Presented development results will provide background and insight in achieving maximal effective radiated power (ERP) to that of legacy S-Band antennas while optimizing on gain variation effects across weapon system roll angles to increase overall link availability and C-Band telemetry data quality.

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